"ARTICULATING STONE BASKET"

TECHNICAL FIELD

The present invention relates generally to surgical retrieval instruments and relates more specifically to a surgical retriever or stone basket in which the tip can be articulated.

BACKGROUND OF THE INVENTION

Stone baskets for capturing and extracting stones from ureters are well known. Such instruments typically comprise a basket at the forward end of an elongated sheath. Wires disposed within the sheath connect the basket to a handle at the opposite end of the sheath. Various mechanisms for expanding and contracting the basket may be associated with the handle.

Today's stone baskets and graspers are being used for purposes other than simply capturing a stone in a ureter. They must also be able to reach the kidney, capture a stone, reposition it, remove it, or hold it for adjunctive treatment. Larger baskets can capture larger stones but perform poorly in capturing smaller stones. Known stone baskets cannot readily release a stone if complications arise and there is a need to exit quickly. On occasion, a physician may actually have to cut the basket wires in order to release a stone, which presents the obvious complication of having to extract the basket wires from the patient.

SUMMARY OF THE INVENTION

Stated generally, the present invention comprises a medical retrieval device having a handle. An actuator is

mounted to the handle for rotational movement. A basket has at least three legs, an adjacent two of the legs being connected to a first location on the actuator radially spaced apart from its axis of rotation. The remainder of the legs are connected to a second location on the actuator radially spaced apart from the axis of rotation such that rotation of the actuator displaces the two legs in a first direction and displaces the remainder of the legs in a second direction different from the first direction. Rotation of the actuator thus articulates the basket

In a disclosed embodiment the medical retrieval device has a hollow sheath attached to and extending forward from the handle. A slide is attached to the handle for longitudinal movement, and the slide is movable along a path between a rearward location and a forward location. The actuator is mounted to the slide for rotational movement. The basket is retracted within a forward portion of the sheath when the slide is in the rearward location, and the basket is extended forward of the forward end of the sheath when the slide is in the forward location. Thus longitudinal movement of the slide extends and retracts the basket, and rotation of the rotary actuator articulates the basket.

In another disclosed embodiment the sheath is attached to the slide such that longitudinal movement of the slide displaces the sheath to cover or to expose the basket.

In the disclosed embodiments the slide assembly is moved along its longitudinal path by the operator applying pressure with his thumb to a button on the top of the slide assembly. In some disclosed embodiments the rotary actuator consists of a drum mounted to the slide for rotation. A thumb wheel is operatively associated with the drum such that rotation of the wheel by the operator's thumb causes the drum to rotate to articulate the basket.

A special feature of the disclosed embodiment is that, after having grasped a stone, the basket is capable of releasing

it. Thus if a physician begins to withdraw a stone and finds it is too large to pass through a physiological constriction such as the intramural ureter, or if complications arise which require rapid extraction of the stone basket, the physician can articulate the basket to spread the basket wires, thereby releasing the stone.

Objects, features, and advantages of the present invention will become apparent upon reading the following specification, when taken in conjunction with the drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a medical retrieval device according to a preferred embodiment of the invention.

FIG. 2 is a top view of the medical retrieval device of FIG. 1.

FIG. 3 is a side view of the handle of the medical retrieval device of FIG. 1.

FIG. 4 is a cross-sectional view taken along line 4–4 of FIG. 3.

FIG. 5 is a side view of a slide of the medical retrieval device of FIG. 1.

FIG. 6 is a front view of the slide of FIG. 5.

FIG. 7 is a front perspective view of the slide of FIG. 5.

FIG. 8 is a rear perspective view of the slide of FIG. 5.

FIG. 9 is a side view of a thumb wheel of the stone basket of FIG. 1.

FIG. 10 is a front view of the thumb wheel of FIG. 9.

FIG. 11 is a cross-sectional view taken along line 11–11 of FIG. 9.

FIG. 12 shows the assembly of the slide of FIG. 5 onto the handle of FIG. 3.

FIG. 13 shows the assembly of the thumb wheel of FIG. 9 onto the handle and slide assembly of FIG. 12.

FIG. 14 shows the assembled handle, slide, and thumb wheel of FIG. 13.

FIG. 15 is an enlarged perspective view of the basket of the medical retrieval device of FIG. 1.

FIG. 16 is a side cutaway view of the medical retrieval device of FIG. 1 with the basket in a retracted position.

FIG. 17 is a side cutaway view of the medical retrieval device of FIG. 1 with the basket in an extended position.

FIG. 18 is a front view of the basket in the extended position of FIG. 17.

FIG. 19 is a side cutaway view of the medical retrieval device of FIG. 1 with the basket in an extended and articulated position.

FIG. 20 is a front view of the basket in the extended and articulated position of FIG. 19.

FIG. 21 is an enlarged perspective view of a first alternate embodiment of a basket for use with the actuation mechanism of the device of FIG. 1.

FIG. 21 is an enlarged perspective view of a first alternate embodiment of a basket for use with the actuation mechanism of the device of FIG. 1.

FIG. 22 is an enlarged perspective view of a second alternate embodiment of a basket for use with the actuation mechanism of the device of FIG. 1.

FIG. 23 is an enlarged perspective view of a third alternate embodiment of a basket for use with the actuation mechanism of the device of FIG. 1.

FIG. 24 is an exploded perspective view of a first alternate embodiment of an articulation drive arrangement.

FIG. 25 is an assembled side view of the drive arrangement of FIG. 24.

FIG. 26 is a side view showing the drive arrangement of FIG. 24 actuated in a first direction.

FIG. 27 is a side view showing the drive arrangement of FIG. 24 actuated in a second direction.

FIG. 28 is an exploded perspective view of a second alternate embodiment of an articulation drive arrangement.

FIG. 29 is an assembled side view of the drive arrangement of FIG. 28.

FIG. 30 is a side view showing the drive arrangement of FIG. 28 actuated in a first direction.

FIG. 31 is a side view showing the drive arrangement of FIG. 28 actuated in a second direction.

FIG. 32 is a side view of an alternate embodiment of a rotary actuator which comprises radial arms instead of a rotary drum.

FIG. 33 side view of an alternate embodiment of a stone basket in which only one set of basket arms is articulated.

FIG. 34 is an enlarged side view of the slide and rotary actuator of the embodiment of FIG. 33.

FIG. 35 is a side view of an alternate embodiment of a stone basket in which the sheath is connected to the slide, showing the sheath in an extended position so as to cover the basket.

FIG. 36 is a side view of the alternate embodiment of FIG. 35 showing the sheath in a retracted position so as to expose the basket.

FIG. 37 is an exploded perspective view of an alternate embodiment of a medical retrieval device which employs linear actuators to articulate the basket.

FIG. 38 is an assembled perspective view of the medical retrieval device of FIG. 37.

FIG. 39 is a top view of the medical retrieval device of FIG. 37.

FIG. 40 is a side view of the medical retrieval device of FIG. 37.

FIG. 41 is a section view taken along line 41–41 of FIG. 40.

FIG. 42 is a horizontal cross-sectional view of the slide of the medical retrieval device of FIG. 37 showing the linear actuators in their retracted positions.

FIG. 43 is a horizontal cross-sectional view of the slide of FIG. 42 showing a first linear actuator advanced to articulate the basket in a first direction.

FIG. 44 is a horizontal cross-sectional view of the slide of FIG. 42 showing a second linear actuator advanced to articulate the basket in a second direction.

FIGS. 47–49 are perspective views showing a first method of use of the stone basket of FIG. 1 to retrieve a stone from a lumen, in which:

FIG. 47 shows the basket retracted within the forward end of the sheath;

FIG. 48 shows the basket in its deployed position to receive the stone; and

FIG. 49 shows the stone captured within the basket.

FIGS. 50–53 are perspective views showing a second method of use of the stone basket of FIG. 1 to retrieve a stone from a lumen, in which:

FIG. 50 shows the basket in its normal, extended position;

FIG. 51 shows the basket in its downwardly articulated position, open and ready to receive a stone;

FIG. 52 shows the basket in its downwardly articulated position maneuvered to position the basket around the stone; and

FIG. 53 shows the basket retracted to capture the stone.

FIGS. 54 and **55** are perspective views showing a third method of use of the stone basket of FIG. 1 to retrieve a stone from a lumen, in which:

FIG. 54 shows the basket in its upwardly articulated position, open and ready to receive a stone;

FIG. 55 shows the basket in its upwardly articulated position maneuvered to position the basket around the stone.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENT

Referring now to the drawings, in which like numerals indicate like elements throughout the several views, FIGS. 1 and 2 show a stone basket **10**. The stone basket **10** includes a handle **12**, a sheath **14** attached to the forward end of the body, a basket **16** extending from the forward end of the sheath **14**, and a slide assembly **18** slidably mounted to the body **12**.

FIGS. 3 and 4 illustrate the handle **12** of the stone basket **10** in further detail. The handle **12** includes a handle body **20**. A grip **22** contoured to fit the hand of the operator is formed along the lower edge of the handle body **20**. A hollow nose **24** is formed at the forward end of the handle body **20**. A longitudinal slot **26** extends through the handle body and communicates with the hollow nose **24**. An elongated spine **27** defines the upper edge of the longitudinal slot **26**. As shown in FIG. 4, an upwardly opening channel **28** is formed adjacent to the spine **27** along one lateral edge of the longitudinal slot **26**. A downwardly extending groove **30** is formed along the opposite lateral edge of the longitudinal slot **26**.

FIGS. 5–8 show a thumb slide **34** of the slide assembly **18**. The thumb slide **34** includes a body portion **35** and a button member **36** atop the body portion **35** and adapted to receive the thumb of the operator. The button member **36** includes a ribbed upper surface **38** to minimize slippage of the operator's thumb on the button member **36**. Immediately beneath the button member **36** a recess **40** is formed in a lateral edge of the body potion **35**. At the lower edge of the body portion **35** along the

same lateral edge in which the recess **40** is formed is a runner **42**. A transverse keyway **44** having a semicircular upper edge **45** extends upward from the lower face of the body portion **35**.

FIGS. 9–11 depict a thumb wheel **46** of the slide assembly **18**. The thumb wheel **46** has a ribbed periphery **48**, again to minimize slippage of the operator's thumb. The thumb wheel further has a raised tab **49** formed at the twelve o'clock position which provides a visual and tactile indicator to the physician as to the angular orientation of the wheel. The thumb wheel **46** has a concentric, disk-shaped boss **50** formed on its inner surface. A cylindrical drum **52** is formed concentric with the boss **50** and extends inward from the thumb wheel **46**. The drum **52** is dimensioned to fit within the keyway **44** of the thumb slide **34**. A threaded bore **54** is formed in the free end of the drum **52**. Upper and lower radial passages **56**, **58** are formed in the drum **52** and extend from the threaded bore **54** radially outward to the upper and lower edges, respectively, of the drum.

Assembly of the thumb slide **34** and thumb wheel **46** onto the handle body **20** is illustrated in FIGS. 12–14. Referring first to FIG. 12, the thumb slide **34** is angled so that the lower end of the thumb slide can be inserted through the longitudinal slot **26** from the side of the handle body **20** opposite the downwardly extending groove **30**. The thumb slide **34** is then pivoted into its upright position, with the spine **27** of the handle body **20** fitting within the recess **40** of the thumb slide. The runner **42** on the lower lateral edge of the thumb slide **34** rides in the groove **30** in the lateral edge of the longitudinal slot **26**.

Referring now to FIGS. 13 and 14, with the thumb slide **34** slidably mounted within the longitudinal slot **26** in the handle **12**, the drum **52** of the thumb wheel **46** is inserted through the keyway **44** in the thumb slide. To retain the thumb wheel **46** on the thumb slide **34**, the threaded shank of a screw

60 is inserted into the threaded bore **54** of the thumb wheel. The thumb slide **34** is now slidably mounted to the handle **12**, and the thumb wheel **46** is rotatably mounted to the thumb slide.

FIG. 15 is an enlarged view of the basket **16** and the forward end of the sheath **14**. A pair of elongated tubes **64**, **66** are slidably disposed within the sheath **14**. The basket **16** includes a pair of upper legs **70a**, **70b** and a pair of lower legs **70c**, **70d**. The upper legs **70a**, **70b** are formed from a single loop **72** of a flat cross-sectional wire. The ends **74a**, **74b** of the loop **72**, and thus the rearward ends of the legs **70a**, **70b**, are attached to the upper elongated tube **64** which is telescopically disposed within the sheath **14**.

Similarly, the lower two legs **70c**, **70d** of the basket **16** are formed from a single loop **76** of round cross-sectional wire. The ends **78a**, **78b** of the loop **76**, and thus the rearward ends of the legs **70c**, **70d**, are attached to the lower elongated tube **66** which is telescopically disposed within the sheath **14**. The basket legs **70a–70d** of the disclosed embodiment are secured to the tubes **64**, **66** by inserting the rearward ends of the legs into their respective tubes and then crimping the tube ends. However, it will be appreciated that other means for mounting the basket legs to the tubes may be employed, including adhesives, welding, and the like.

The upper and lower loops **72**, **76** of the basket **16** are joined at their forward central portions at a junction **80**. In the embodiment of FIG. 15, the junction is formed by tying the two loops **72**, **76** together. The upper loop **72** is formed, and then the lower loop **76** is tied over it using a larkshead knot.

FIGS. 16–20 illustrate further details of the stone basket **10** and its operation. The elongated tubes **64**, **66** are telescopically disposed within the sheath **14** of the stone basket **10**. The basket **16** is mounted to the forward ends of the tubes **64**, **66**. The rearward ends of the tubes **64**, **66** are operatively

connected to the thumb wheel **46** as follows. An upper cable **82** has its forward end connected to the rearward end of the upper tube **64**, such as by crimping, adhering, welding, or otherwise bonding the cable to the tube. Similarly, a lower cable **84** has its forward end connected to the rearward end of the lower tube **66**. The forward ends of the cables **82**, **84** are inserted into the upper and lower radial passages **56**, **58** on the drum **52** of the thumb wheel and secured by adhering, welding, or otherwise bonding the cable ends within the passages. In the alternative, the ends of the cables **82**, **84** can be inserted through the passages and into the bore **54**, where subsequent insertion of the screw **60** will clamp the cable ends.

Operation of the stone basket **10** will now be described with reference to FIGS. 16–20. In FIG. 16, the slide assembly **18** is in a rearward position with respect to the handle **12**, and the basket **16** is retracted within the forward end of the sheath **14**. When the slide assembly **18** is advanced as shown in FIG. 17, the tubes **64**, **66** are telescopically advanced within the sheath **14**, extending the basket legs **70a**–**70d** from the forward end of the sheath. The basket legs **70** are preferably formed from a shape memory metal such as nitinol, such that the legs, once freed from the confines of the sheath **14**, spring outward into their predetermined configurations.

FIG. 18 is a front view of the basket **16** when extended as shown in FIG. 17. The basket **16** is shaped like a spoon, with the upper legs **70a**, **70b** forming the upper edge of the spoon and the lower legs **70c**, **70d** forming the bowl. In its normal open configuration, the lower legs **70c**, **70d** are separated by a distance d_1.

In FIG. 19 the thumb wheel **46** is rotated rearward, in the direction indicated by the arrow **91**. This rotation exerts a tension on the upper cable **74**, drawing the upper tube **64** rearward. Simultaneously the lower cable **76** is advanced. The cables **74**, **76** have sufficient stiffness that the lower tube **66** is

advanced. Thus the tubes **64**, **66** move in reciprocal directions. This retraction of the upper tube **64** and extension of the lower tube **66** causes the upper basket legs **70a**, **70b** to retract and the lower basket legs **70c**, **70d** to extend, thus articulating the basket **16** upward.

Referring to FIGS. 19 and 20, articulation of the basket **16** causes several advantageous effects. First, as can be seen in FIG. 19, the junction **80** is displaced rearward of a plane **92** defined by the forward edge of the basket **16**. Thus if a stone is lodged against a wall perpendicular to the longitudinal axis of the device **10**, the junction **80** does not prevent the basket **16** from being advanced right up against the wall to capture the stone. Second, as can be seen in FIG. 20, in the basket's articulated configuration the lower legs 70c, 70d are spread apart by a distance d_2, which is larger than distance d_1 of FIG. 18. Thus articulation of the basket **16** causes the two lower legs **70c**, **70d** to spread apart in clamshell fashion, thus making it easier to maneuver the basket around a stone.

The arrangement by which movement of one of the tubes **64**, **66** causes an equal-but-opposite movement of the other tube provides the advantage that rotation of the thumb wheel **46** by a given amount results in twice the effective "throw." Thus less movement of the thumb wheel **46** is required to effect the same range of articulation. The throw of the device is also determined by the diameter of the drum **52**.

While the foregoing embodiment employs a pair of tubes **64**, **66** telescopically disposed within the sheath **14** to facilitate coupling the basket legs **70a–70d** to the drum **52** of the thumb wheel **46**, it will be appreciated that the basket wires may instead be made sufficiently long to extend the length of the sheath and couple directly to the drum. In the alternative, it will be appreciated that more than two tubes can be used to couple the basket legs **70a–70d** to the drum **52** of the thumb wheel **46**. For example, each leg **70a–70d** can be attached to its own tube,

with more than one tube attached within a given radial passage of the drum **52**.

Further, while the foregoing embodiment **10** provides a thumb wheel **46** which the operator turns to rotate the drum **52** to articulate the basket **16**, it will be appreciated that the thumb wheel is not essential to the operation of the device. For example, a lever coupled to the drum could be used in lieu of the thumb wheel, or an electric motor could be arranged to rotate the drum when actuated. Similarly, while the slide assembly **18** of the embodiment **10** is manually advanced and retracted along its path of movement on the handle **12** by the operator's finger, it will be appreciated that alternate arrangements for longitudinally displacing the slide assembly with respect to the handle may be used, including an electric motor or a wheel and pulley.

FIGS. 21–23 show alternate embodiments of baskets which can be used with the actuation mechanism hereinbefore described. Referring first to FIG. 21, a basket **116** includes basket legs **170a–170d**. The upper legs **170a**, **170b** of the basket **116** are formed from a single loop **172** of a flat cross-sectional wire. The ends **174a**, **174b** of the loop **172**, and thus the rearward ends of the legs **170a**, **170b**, are attached to the upper elongated tube **64** which is telescopically disposed within the sheath **14**.

Similarly, the lower two legs **170c**, **170d** of the basket **116** are formed from a single loop **176** of round cross-sectional wire. The ends **178a**, **178b** of the loop **176**, and thus the rearward ends of the legs **170c**, **170d**, are attached to the lower elongated tube **66** which is telescopically disposed within the sheath **14**.

The upper and lower loops **172**, **176** of the basket **116** are joined at their forward central portions by a fastener **180**. The fastener **190** can be a ring through which the upper and

lower loops **172**, **176** are passed before attaching the loop ends **174a**, **174b**, **178a**, **178b** to their respective tubes **64**, **66**.

Referring next to FIG. 21, a basket **216** includes two upper legs **270a**, **270b** formed from a single loop **272** of a round cross-sectional wire. The ends **274a**, **274b** of the loop **272**, and thus the rearward ends of the legs **270a**, **270b**, are attached to the upper elongated tube **64** which is telescopically disposed within the sheath **14**.

Similarly, the lower two legs **270c**, **270d** of the basket **116** are formed from a single loop **276** of flat cross-sectional wire. The ends **278a**, **278b** of the loop **276**, and thus the rearward ends of the legs **270c**, **270d**, are attached to the lower elongated tube **66** which is telescopically disposed within the sheath **14**.

The upper and lower loops **272**, **276** of the basket **216** are joined at their forward central portions at a junction **280** without use of a separate fastener. The upper loop **272** is bent at its forward end to form an eye **292**. Several turns **294** of the lower loop **276** wrap through this eye **292**.

Another basket **316** is disclosed in FIG. 23. The two upper legs **370a**, **370b** of the basket **316** are formed from a single loop **372** of a round cross-sectional wire. Both ends **374a**, **374b** of the upper loop **372** are attached to the upper tube **64**. The basket **316** includes only one lower leg **370c**, which is formed from a wire having a flat cross-section.. The rearward end **378** of the lower leg **370c** is attached to the lower tube **66**. The forward end of the lower leg **370c** is bent to form a hook **398** which captures the forward central portion of the upper loop **372**.

It will be understood that the baskets **16**, **116**, **216**, and **316** are disclosed by way of example, and that the actuating mechanism of the device **10** is not limited to use with these particular basket configurations but rather can be used with a wide variety of basket configurations.

In the device **10** described above, the elongated tubes **64**, **66** are attached by cables **74**, **76** to the circumference of the drum **52**. FIGS. 24–31 show alternate embodiments for coupling the tubes to the drum wherein the elongated tubes **64**, **66** are attached to a lateral face of a drum and reciprocate as the drum is rotated.

Referring first to FIGS. 24 and 25, the drum **152** has a lateral face **161**. Upper and lower pins **162**, **163** project outward from the lateral face **161** of the drum **152**. Elongated tubes **164**, **166** have hooks or eyelets **168** formed at their rearward ends which engage the pins **162**, **163** on the lateral face **161** of the drum **152**. As the drum **152** rotates in a counterclockwise direction as shown by the arrow **173** in FIG. 26, the upper pin **162** on the drum rotates toward the left, and the upper tube **164** coupled to the pin **162** is displaced forward. Simultaneously, the lower pin **163** on the drum **152** rotates toward the right, displacing the lower tube **166** rearward. If the drum **152** is rotated in a clockwise direction as shown by the arrow **175** in FIG. 27, the upper pin **162** on the drum rotates toward the right, and the upper tube **164** coupled to the pin **162** is withdrawn. Simultaneously, the lower pin **163** on the drum **152** rotates toward the left, advancing the lower tube **166**.

FIGS. 28–31 portray a similar arrangement which differs in the manner in which the tubes are coupled to the drum. Referring first to FIGS. 28 and 29, a drum **252** has a lateral face **261**. Upper and lower holes **262**, **263** are formed in the lateral face **261** of the drum **252**. Elongated tubes **264**, **266** have lateral arms **268** formed at their rearward ends which engage the holes **262**, **263** on the lateral face **261** of the drum **252**. As the drum **252** rotates in a counterclockwise direction as seen in FIG. 30, the upper hole **262** of the drum rotates toward the left, displacing the upper tube **264** forward. Simultaneously, the lower hole **263** of the drum **252** rotates toward the right, and the lower tube **166** coupled to the hole **263** is pulled rearward.

When the drum **252** is rotated in a clockwise direction as seen in FIG. 31, the upper hole **262** of the drum rotates toward the right, and the lower hole **263** of the drum **252** rotates toward the left, retracting the upper tube **264** and advancing the lower tube **266**.

Whether the elongated tubes are attached to the cylindrical wall of the drum or to a lateral face of the drum, the common feature is that the tubes are coupled to the drum at locations which are radially offset from the axis of rotation of the drum so as to be linearly displaced as the drum is rotated. Other well-known mechanical expedients for converting rotational motion into linear motion can also be substituted. For example, instead of using a drum, the tubes **64, 66** can be coupled as shown in FIG. 32 to a rotatably mounted actuator **452**. The cables **74, 76** which link the tubes to the actuator **452** are fastened to the ends of radial arms **453** at locations which are radially offset from the axis of rotation of the actuator. Henceforth, for purposes of this application an element which is rotatably mounted to the device and which includes structure radially offset from its axis of rotation to which the basket wires are linked will be referred to as a "rotary actuator."

As will be appreciated, in the embodiments **10, 110, 210,** and **310** described above, the motion of the basket legs is dependent, that is, movement of one basket leg is necessarily accompanied by movement of all of the other legs, either in the same direction or in an opposite direction. Stated differently, in the embodiments **10, 110, 210,** and **310** it is not possible to move any leg of the basket independently of the other legs. FIGS. 33 and 34 illustrate an alternate embodiment of a stone basket **510** in which independent movement is possible of one or more of the basket legs with respect to the other legs. In the embodiment **510** only one set of basket legs is articulated. The upper tube **64** to which the upper basket legs **70a, 70b** are attached is connected to a location on the periphery of a drum

552 by means of a cable 82, in the same manner previously explained. However, the lower tube 66 to which the lower legs 70c, 70d are connected is attached to the front of the slide 518 by means of a cable 584. In FIGS. 31 and 32 the cable 584 has a ferrule 585 at its free end which fits into a cooperating recess 586 in the lateral edge of the slide 518, with the cable being received through a narrow slot 587 in the front wall of the slide. Thus longitudinally advancing and retracting the slide 518 extends and retracts the basket 16, and rotating the drum 552 extends or retracts the upper legs 70a, 70b of the basket to effect articulation.

Referring now to FIGS. 35 and 36, still another embodiment 610 of a medical retrieval device includes a handle 612, a sheath 614, a basket 616, and a slide 618. As in previous embodiments the slide 618 is mounted to the handle 612 for longitudinal movement. In contrast to previously described embodiments, however, the sheath 614 is not fixedly mounted to the handle 612 but instead is mounted to the slide 618 for longitudinal movement with respect to the handle. In addition, a rotary actuator 652 is mounted to the handle 612 at a point rearward of the path of movement of the slide 618 and does not move with the slide. The tubes 664, 666 extend through the sheath 614 and through a longitudinal opening in the slide 616. Cables 682, 684 connect the rearward ends of the tubes 664, 666 to the rotary actuator 652.

In the embodiment 610, when the slide 618 is in its forward position as shown in FIG. 35, the basket 616 is covered. The basket 616 is deployed by retracting the slide 618 in the direction indicated by the arrow 692 to expose the basket, as shown in FIG. 36. Advancing the slide 618 covers the basket 616 or, if a stone has been maneuvered into the basket, tightens the basket around the stone to enable it to be withdrawn from the patient. As in previous embodiments,

rotating the actuator **652** advances one of the tubes **664**, **666** and retracts the other, thereby articulating the basket **616**.

FIGS. 37–44 illustrate another alternate embodiment of a medical retrieval device **710** according to the present invention. The embodiment **710** is characterized by the use of linear actuators to articulate a basket, instead of the rotary actuators used in the embodiments previously described.

Looking first at FIGS. 37–41, the device **710** includes a handle **712**, a slide assembly **718**, a sheath (not shown), and a basket (also not shown). The handle **712** comprises a handle body **720** consisting of two handle body halves **720a**, **720b** (FIG. 37). The handle body halves **720a**, **720b** are mirror images of one another, with the exception that one half **720a** has guide pins and the other half **720b** has corresponding holes into which the pins of the first half **720a** fit.

The handle **712** further comprises a grip **722** contoured to fit the hand of the operator and formed along the lower edge of the handle body **720**. A hollow nose **724** is formed at the forward end of the handle body **720**. An opening **726** extends through the hollow nose **724**. Each of the body halves **720a**, **720b** has a longitudinal slot **727**. Mutually opposed, inwardly projecting longitudinal ribs **729** (FIG. 37) are formed on the inner surfaces of the body halves **720a**, **720b**. A longitudinal groove **731** is formed in the upper surface of the handle **712**.

The slide assembly **718** comprises a body portion **735** and a button member **736** atop the body portion **735** and adapted to receive the thumb of the operator. The button member **736** includes a ribbed upper surface **738** to minimize slippage of the operator's thumb on the button member **736**. A narrowed neck portion **739** connects the button member **736** to the body portion **735**. A pair of longitudinally extending cylindrical recesses **741** are formed in the body portion **735** adjacent the lateral edges of the body potion **735**. Recesses **743** are formed in the lower lateral edges of the body portion **735**.

Like the embodiments previously described, the device **710** includes a pair of elongated tubes **764**, **766** which are connected to the basket at their forward ends. The rearward ends of the tubes **764**, **766** are connected to hubs **768**. Each hub **768** includes a flange **769** having concave front and rear edges **771**, **773** adapted to receive a finger of an operator. Each hub **768** further includes a cylindrical body portion **775** to which the tubes **764**, **766** are mounted.

The device **710** will be understood to have a sheath attached to the forward end of the handle **720**, like the embodiment **10** described above. Further, the tubes **764**, **766** will be understood to extend through the sheath to a basket at the forward end of the sheath. The basket and sheath are not shown in FIGS. 37–44 for convenience of description.

To assemble the device **710**, the tubes **764**, **766** and the cylindrical portions **775** of the hubs **768** are inserted through the longitudinal slots **727** in their respective body halves **720a**, **720b** so that the tubes and the cylindrical portions are located on the inner side of the body halves, and the flanges **769** of the hubs **768** are located on the outer side of the body halves. The tubes **764**, **766** are inserted through the opening **726** in the nose **724** and through the sheath. The cylindrical portions **775** of the hubs **768** are next inserted into the longitudinally extending cylindrical recesses **741** in the body portion **735** of the slide assembly **718**. The body halves **720a**, **720b** are then assembled, capturing the slide assembly **718** therebetween. The neck portion **739** of the slide assembly **718** rides within the longitudinal groove **731** in the upper surface of the handle **712**. The recesses **743** in the lower lateral edges of the body portion **735** ride on the inwardly projecting longitudinal ribs **729** on the inner surfaces of the body halves **720a**, **720b**. Thus the slide assembly **718** is freely slidable between a rearmost position defined by the rearward end of the longitudinal groove **731** and

a forward position defined by the forward end of the longitudinal groove.

To use the device **710**, the basket is extended and retracted by advancing or withdrawing the slide assembly **718**, in the same manner explained above with respect to the device **10**. When the hubs **768** are both in their rearmost positions, as shown in FIG. 42, the basket is in its normal, unarticulated position. If it is desired to articulate the basket toward the right, the left hub **768** is advanced, as shown in FIG. 43, causing the tube **764** to extend. To articulate the basket toward the left, the right hub **768** is advanced, as shown in FIG. 44, causing the tube **766** to extend.

FIGS. 45 and 46 illustrate an alternate embodiment of a slide assembly **818** for use with a handle (not shown) similar to the handle **712** of the previously described embodiment **710**. The slide assembly **818** includes a body portion **835** which will be understood to be configured similar to the body portion **735**, with the exception that the body portion **835** has only a single longitudinally extending cylindrical recesses **841**. The first tube **864** is fixedly attached to the body portion **835** of the slide assembly. The second tube **866** has a hub **868** connected to its rearward end. The hub **868** is slidably mounted to the body portion **835** in the same manner as previously described above with respect to hubs **768** and body portion **735**. The hub **868** comprises a laterally extending flange **869**. The hub **868** mounts to a handle as previously described, with the flange **869** extending through one of the slots (*e.g.*, slots **727**) in the handle. Since there is only one hub **768**, the second slot in the handle can be eliminated.

To use a device with the slide assembly **818**, the slide assembly is advanced or retracted to extend or withdraw the tubes **864**, **866** and hence the basket attached to the forward ends of the tubes. The hub **868** is normally in its rearward position, as shown in FIG. 45. To articulate the basket, the hub

868 is advanced, as shown in FIG. 46, causing the tube **866** to advance with respect to the body portion **835** while the second tube **864** remains stationary with respect to the body portion **835**.

According to this arrangement, the basket can be steered in only one direction. If desired, the "normal" position of the hub **868** can be on the lateral centerline of the body portion **835**, whereby retracting the hub rearward of its normal position, to the orientation depicted in FIG. 45, will steer the basket in a first direction, and moving the hub forward of its normal position, as shown in FIG. 46, will steer the basket in the opposite direction.

The device **10** and its variations can be used to extract a stone from the body of a patient in at least three different ways. The first way, illustrated in FIGS. 47–49, is a conventional method of using a stone basket. For purposes of example, a duct **900** such as a ureter. The forward end of the device, with the basket **16** contained within the sheath **14**, is maneuvered past a stone **902**, as shown in FIG. **47**. The basket **16** is then deployed, as shown in FIG. **48**. As the basket **16** is withdrawn back past the stone **902**, as shown in FIG. 49, the stone is captured in the basket. The basket is then retracted (or the sheath advanced, depending upon the embodiment) to tighten the wires around the stone. The device with captured stone is then extracted from the patient's body.

Use of the device **10** to capture a stone **902** from the body of a patient according to a second method will now be explained with reference to FIGS. **50–53**. With the basket **16** retracted within the sheath **14**, the forward end of the device is inserted into the patient to a location adjacent the target site. As the forward end of the device nears the stone **902**, the basket **16** is opened. As shown in FIG. 50, the four basket wires **70a–70d** expand. The basket **16** is then articulated downward, as shown in FIG. 51. The lower basket wires **70c**, **70d** retract, and the

upper basket wires **70a**, **70b** extend, causing the basket to tip downward. The device is then advanced, the basket **16** "scooping" up the stone **902** as shown in FIG. 52. The basket is then partially retracted, as shown in FIG. 53, to tighten the basket wires **70a–70d** around the stone **902**.

A third method for retrieving a stone **902** from the body of the patient is shown in FIGS. 54 and 55. The first step is identical to the first step of the previous method, as depicted in FIG. **50**. In this expanded but unarticulated configuration, the junction **72** of the basket **16** is the forwardmost element of the device. With the basket **16** thus deployed, the device is actuated to articulate the basket upward. The lower basket wires **70c**, **70d** extend, and the upper basket wires **70a**, **70b** retract, causing the basket to tip upward, as shown in FIG. 54. This articulation causes the junction **72** to be displaced upward and rearward, such that the junction is no longer the forwardmost point of the device. In addition, articulation causes the lower two legs **70c**, **70d** to spread apart in clamshell fashion, thereby creating a larger opening to facilitate maneuvering the basket **16** around the stone **702**.

The device is now maneuvered to the position shown in FIG. 55, where the basket **16** surrounds the stone **702**. The slide is then displaced rearward to partially retract the basket **16**, causing the basket legs **70a–70d** to tighten around the stone **702**, as previously described with respect to FIG. 53. With the stone **702** thus snared, the device is withdrawn to remove the stone from the duct **900**.

In the case of larger stones whose diameter exceeds the depth of the basket **16**, the basket can be articulated to retract the upper legs **70a**, **70b** before displacing the slide rearward. In this manner the upper legs **70a**, **70b** will engage the stone above its centerline, thereby providing a more secure grasp.

Finally, it will be understood that the preferred embodiment has been disclosed by way of example, and that

other modifications may occur to those skilled in the art without departing from the scope and spirit of the appended claims.